Analysis of Passenger Air Travel

28 October, 2016

Background

The Bureau of Transportation Statistics data set contains information on domestic passenger air travel. Specfically, for each flight, the data set includes the origin and destination airport, the date of travel, the duration and delay of travel, and the airline carrier, amongst other details. To make analysis of this large data set tractable, I am going to focus on data from the year 2015, and my primary interest will be looking into flight delays (which I define as arrival >15 minutes after scheduled).

As a preliminary step, I describe below the average number of flights per day, sorted by day of week, month, Airline, and Airport, in order to assess data completeness.

Table 1: Flights by Day of week

Day of Week	Avg Number of Flights Per Day
Monday	16151
Tuesday	15874
Wednesday	16179
Thursday	16149
Friday	16335
Saturday	13226
Sunday	15396

Table 2: Flights by Month

Month	Avg Number of Flights Per Day
January	14706
February	14524
March	15826
April	15935
May	15758
June	16389
July	16548
August	16214
September	15373
October	15545
November	15381
December	15121

Table 3: Flights by Airline

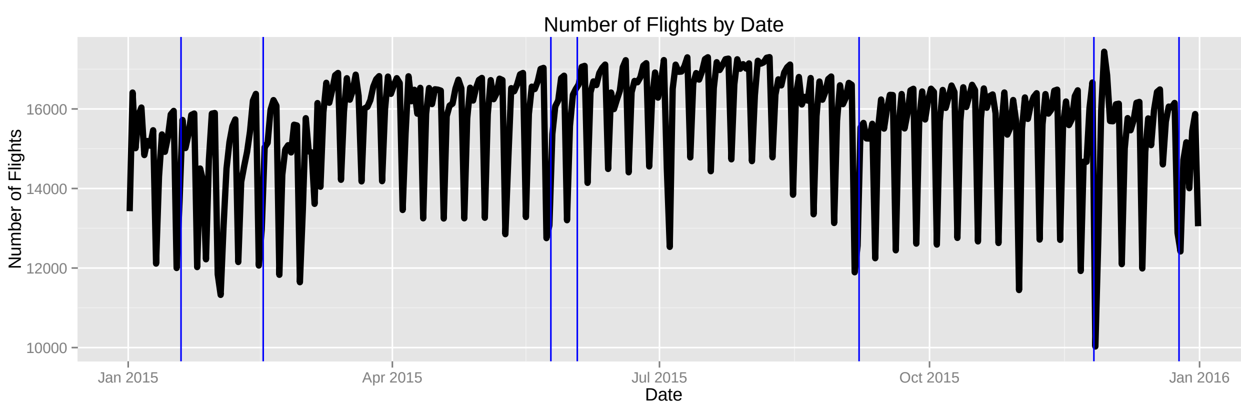
Carrier	Avg Number of Flights Per Day
Southwest Airlines Co.	3394
Delta Air Lines Inc.	2373
American Airlines Inc.	1953
Skywest Airlines Inc.	1577

Carrier	Avg Number of Flights Per Day
Atlantic Southeast Airlines	1511
United Air Lines Inc.	1391
American Eagle Airlines Inc.	762
JetBlue Airways	718
US Airways Inc.	532
Alaska Airlines Inc.	470

Table 4: Flights by Airport

Airport	Avg Departing Per Day	Avg Arrive Per Day	Total Flights Per Day
William B Hartsfield-Atlanta Intl	1024	1023	2047
Chicago O'Hare International	830	828	1659
Dallas-Fort Worth International	694	691	1385
Denver Intl	579	578	1158
Los Angeles International	573	573	1146
San Francisco International	437	437	874
Phoenix Sky Harbor International	434	434	868
George Bush Intercontinental	429	428	856
McCarran International	396	397	793
Minneapolis-St Paul Intl	333	334	667

The plot beneath shows the number of flights for each day of 2015, with the blue lines indicating US Holidays. One potential hypothesis is that there are a larger number of flights around holidays, but this does not seem to be the case.



Delay Rate

In the charts below, I describe the rate at which flights are delayed by day of week, month, airline, and airport. It is interesting to note that there are fewer flights on Saturdays, and these flights are less often delayed. This suggests a correlation between number of flights and delays, which could be investigated as a next step at the airport or airline level.

Table 5: Delayed by Day of week

Day of Week	Delay Rate
Monday	0.19
Tuesday	0.18
Wednesday	0.18
Thursday	0.19
Friday	0.18
Saturday	0.15
Sunday	0.18

Table 6: Delayed by Month

Month	Delay Rate
January	0.20
February	0.23
March	0.19
April	0.16
May	0.18
June	0.23
July	0.20
August	0.18
September	0.12
October	0.12
November	0.15
December	0.20

Table 7: Delayed by Airline

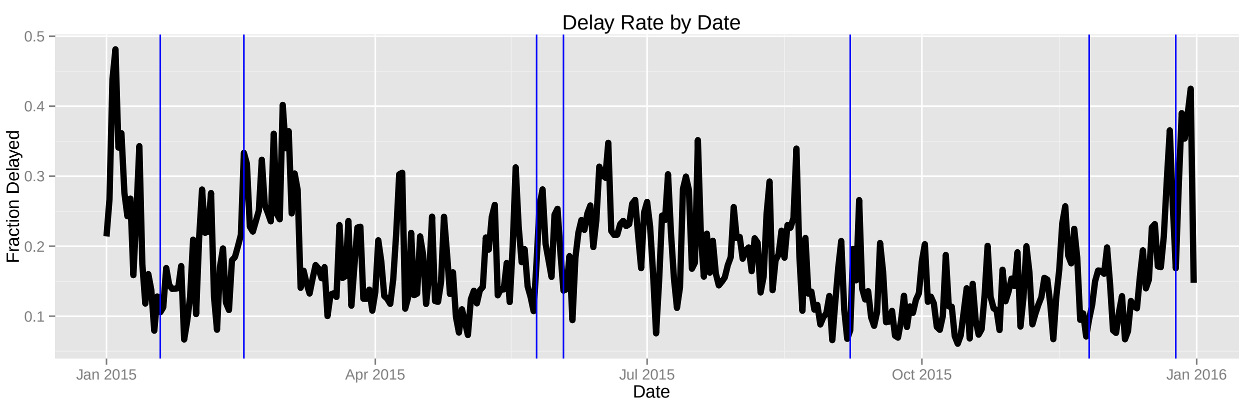
Carrier	Delay Rate
Spirit Air Lines	0.29
Frontier Airlines Inc.	0.25
JetBlue Airways	0.22
American Eagle Airlines Inc.	0.21
United Air Lines Inc.	0.20
Atlantic Southeast Airlines	0.19
Virgin America	0.19
Southwest Airlines Co.	0.18
Skywest Airlines Inc.	0.18
US Airways Inc.	0.18
American Airlines Inc.	0.18
Delta Air Lines Inc.	0.13
Alaska Airlines Inc.	0.12

Carrier	Delay Rate
Hawaiian Airlines Inc.	0.11

Table 8: Delayed by Airport

Airport	Departing Delay Rate	Arriving Delay Rate	Avg Delay Rate
St Cloud Regional	0.31	0.39	0.35
New Castle County	0.39	0.31	0.35
Gustavus	0.43	0.24	0.34
North Bend Muni	0.28	0.31	0.30
Aspen-Pitkin Co/Sardy	0.29	0.30	0.29
Adak	0.41	0.12	0.27
Southeast Texas Regional	0.24	0.27	0.26
Gunnison County	0.23	0.27	0.25
Mammoth Yosemite	0.29	0.21	0.25
Trenton-Mercer County	0.22	0.27	0.24

The plot below shows rate of delay by day, and suggests a spike in delays around Christmas and New Years, as well as an increase in February around President's Day. The full data set contains information on delay cause, and it would be interesting as a next step to investigate that as well– it seems likely that the delays in February are due to weather, while the delays around holidays are due to high traffic.



Delay Rate Model

I was interested in building a model to predict the probability that a given flight would be delayed. To do this, I consider each flight in the 2015 data set a sample, split this set randomly into a training set and holdout set, and trained a regularized logistic regression on the binary dependent variable (delayed or not delayed). As indepedent variables, I used the airline, day of week, month, and average delay rate for the destination and origin airports in the training set.

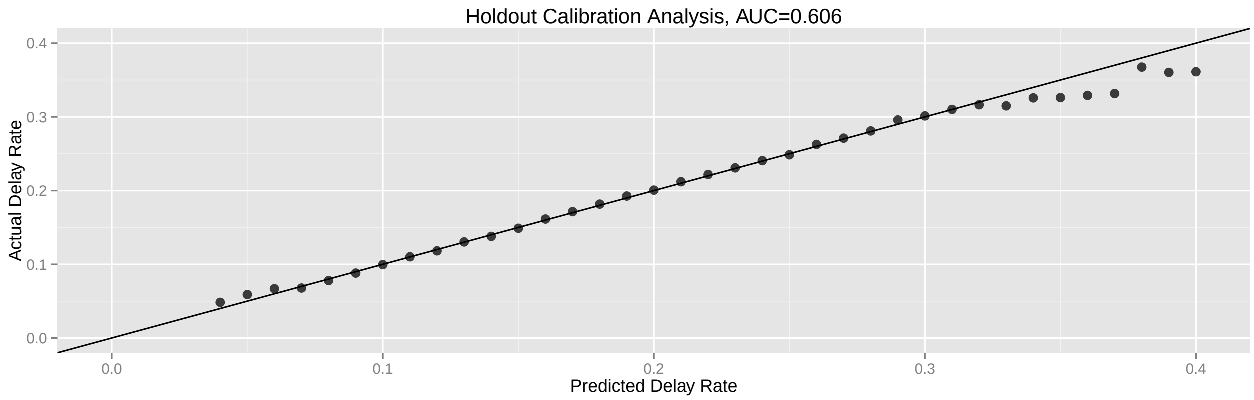
The coefficients determined by the model are listed below. Airports with high delay rates as origins or departures are strong positive predictors of delay, and different periods of time and airlines have reasonable coefficients given the charts above.

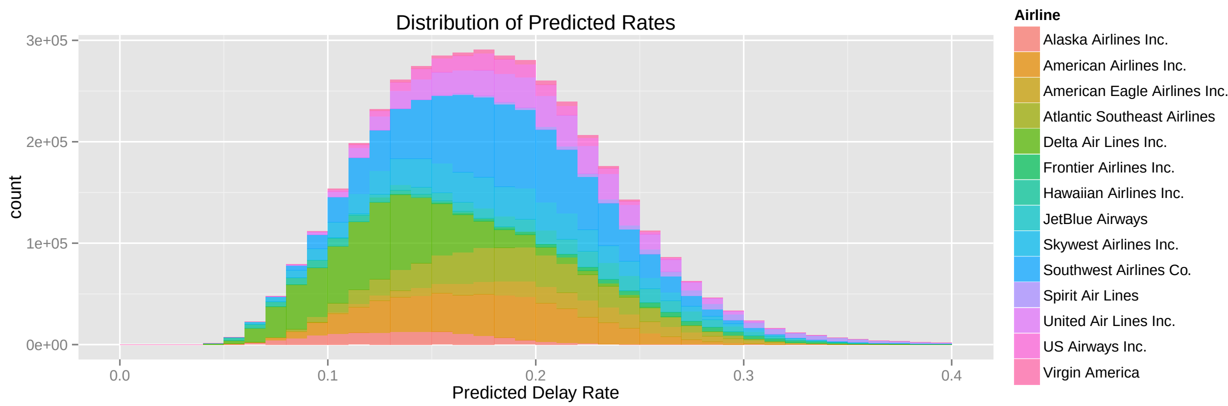
Table 9: Model Coefficients

Feature Name	Coefficients
Origin_delay_rate	5.662
Dest_delay_rate	5.165
(Intercept)	-3.391
AirlineSpirit Air Lines	0.624
month_wordOctober	-0.604
month_wordSeptember	-0.550
AirlineFrontier Airlines Inc.	0.508
month_wordNovember	-0.364
dowSaturday	-0.248
AirlineJetBlue Airways	0.227
month_wordApril	-0.218
AirlineAmerican Eagle Airlines Inc.	0.171
month_wordJune	0.170
AirlineSkywest Airlines Inc.	0.163
month_wordFebruary	0.155
AirlineDelta Air Lines Inc.	-0.146
AirlineSouthwest Airlines Co.	0.146
AirlineAtlantic Southeast Airlines	0.143
month_wordMay	-0.129
month_wordAugust	-0.109
AirlineHawaiian Airlines Inc.	0.104
AirlineUnited Air Lines Inc.	0.098
dowWednesday	-0.090
month_wordMarch	-0.087
dowSunday	-0.079
dowTuesday	-0.070
month_wordJuly	0.030
dowFriday	-0.025
AirlineVirgin America	-0.025
dowThursday	0.021
AirlineAmerican Airlines Inc.	0.016
AirlineUS Airways Inc.	-0.003
month_wordDecember	0.000

The output of the model is summarized in the two plots below. The top plot describes the model performance. This model was able to predict delays in the holdout set better than random- the AUC=0.6 describes the quality with which the predictions rank-orders the flights, and the calibration plot shows quantitative agreement between predicted delay rates and the actual delay rates in the holdout set. The lower plot is the distribution of lateness probability for each flight in the holdout set, colored by airline.

As a next step, a model could be investigated with additional features (simplifying month to season, sorting airports by size, describing the route frequency or distance, proximity to holidays) or using another methodology which might be able to pick up on more subtle interactions between features.





Geographic Visualizations

Below are two plots which provide a visualization of this data. The first plots each airport, with the size proportional to the number of departing flights, and the color indicating the delay rate. The second shows line segments connecting airports, with the thickness of the line segment indicating the frequency of that route.